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THE GREEN TROGOSITID AND RED BELLIED CLERID IN RELATION TO THE CONTROL OF THE MOUNTAIN PINE BEETLE IN SUGAR PINE

Progress Report

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THE GREEN TROGOSITID AND RED BELLIED CLERID IN RELATION TO THE CONTROL OF THE MOUNTAIN PINE BEETLE IN SUGAR PINE

Progress Report

INTRODUCTION.

Control of the mountain pine beetle in sugar pine by use of native predators in lieu of or supplemental to other control methods is much to be desired. The extent to which predators exert controlling action in nature is still an unknown quantity. As time goes on in the development and improvement of control methods, the desirability of learning more about the controlling influence of predators increases in importance. We need to know, first of all, whether predacious insects are highly effective; secondly, whether artificial control methods do great harm by destruction of predators; and finally what the possibilities are in the improvement and encouragement of predators through protection and artificial propogation.

Studies were initiated on this problem during 1937, when the various species of predacious insects in association with the mountain pine beetle in sugar pine were investigated. The results of this preliminary work, assembled in a station report*, established the fact that two predators, the green trogositid, Temnochila virescens and the red bellied clerid, Enoclerus sphegeus are primarily important because of their constant association with the different seasonal broods of the mountain pine beetle and their decided aggressive tendency, both in the larval and adult stages. These facts were further strengthened by positive controlling action in preliminary experiments carried on by caging control. Furthermore, it was found that the habits and seasonal cycle of these two insects followed closely after the seasonal broods of the mountain pine beetle, E. sphegeus on the overwintering and T. virescens on the summer broods.

Investigations of these two insects were continued during 1938 (1) to secure additional data in support of the controlling action of these two species from sugar pines in the field infested by the mountain pine beetle, and from experimental control cages; (2) to learn more of the life history and habits in relation to the mountain pine beetle; and (3) to make a comparative study and evaluation of each species in regard to factors governing control efficiency. While investigating these points, data on other predacious insects were secured to learn about their relative importance. In addition, to these studies, work was initiated on experiments to develop artificial propagation, the results of which are to be included in a separate report.

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*Struble, G. R.; Temnochila virescens and Enoclerus sphegeus in relation to the mountain pine beetle in sugar pine. Berkeley, Calif. Feb. 12, 1938.

The purpose of this progress report is to present the results of the 1938 investigative season in regard to field data and controlled experiments on biological control. These studies were carried on in the same general areas as in 1937, near Wawona, California. The newly established Miami Laboratory, located on the Sierra National Forest, served as a field base. Improved laboratory and rearing facilities aided materially in the accomplishment of this work.

LIFE HISTORY AND HABITS

Temnochila virescens requires one year to complete its development. Eggs are laid throughout June, July and August on sugar pines containing the summer broods of the mountain pine beetle. The larvae which hatch out feed upon the mountain pine beetle broods and do not complete their development until the following summer. Following larval maturity, cells are constructed near the point of last feeding in the phloem or bark, and after a short rest period, pupation occurs. Adults which emerge late in the summer and during the fall hibernate in the bark cracks of overwintering trees, but have never been found to establish broods in them.

Enoclerus sphegeus has a one year life cycle. Eggs are laid during the fall and spring on sugar pines infested by overwintering broods of the mountain pine beetle. The larvae complete their development by the time the emergence of the overwintering D. monticolae brood is over. Then they migrate to the base of the tree where they construct pupal cells in the outer bark and aestivate for a considerable period. New adults begin emergence early in the fall and reach a peak during October.

SEASONAL ABUNDANCE

The occurrence and relative numbers of these predators with the different seasonal broods of the mountain pine beetle is an important factor governing control. The control factor exerted by other predatory and associated insects cannot be overlooked. Hence, in securing field data all insects were considered.

Season of 1938.

Basic data were obtained from 5 overwintering (1937-38) and 8 summer generation sugar pines. Additional information was taken from 6 windfalls which contained summer generation broods. In all, 223.6 square feet of bark area were analyzed completely for D. monticolae broods, predators and associated insects. The areas selected for analysis from each tree were chosen on the basis of representative D. monticolae broods in mature larval and pupal stages. As a rule, 10 square feet of bark area were analyzed from a given representative location on a tree. One or more areas were sampled, depending on the size of the tree, the infested length of bole, and apparent differences in D. monticolae brood. (Photo #1.)

In Table I which follows, a summary of the analyses is presented to show the comparative distribution by seasons of T. virescens E. sphegeus, other predators*, and associates**, in relation to the mountain pine beetle. The numbers of E. sphegeus and T. virescens found in all samples again this year were more constant and abundant than any of the other insect predators.

TABLE I. Comparative Seasonal Abundance of Predators and Associates in Relation to D. monticolae.

Tree #	Area of sample, sq.ft.	Predators per square foot. T.v.c.	E.sph.	All others	Associates per sq.ft.	D.m. per sq.ft.
		Overwinter, 1937-1938				
1	10	0	3.1	3.1		107
2	10	0	.8	.1		91
3	10	0	1.9	2.2		83
4	6	0	5.7	3.5		88
		Summer, 1938				
1	7	.7	0	5.0	.5	45
4	10	2.2	0	5.9	10.4	20
5	8	1.5	0	4.1	1.8	54
9	10	1.3	0	7.1	7.1	33
		Windfalls, summer 1938				
1	10	0	.9	5.5	0	76
2	10	1.2	.1	2.0	.2	45
3	7	.1	0	2.5	.5	76
4	10	.4	0	8.2	12.0	81
5	10	1.7	0	2.4	9.1	31

Close examination of the data presented in this table reveals some rather interesting trends.

1. The absence of T. virescens on overwintering broods and nearly the same conditions found for E. sphegeus on summer broods of D. monticolae is evidently a constant characteristic of the two predators. This is a factor which is definitely influenced by the comparative life history and habits of each.

2. The comparative controlling action of E. sphegeus and T. virescens differs greatly. No correlation between the numbers of E. sphegeus and overwintering D. monticolae brood can be seen, and in addition there is no evidence of any particular control. On the other hand, the presence of T. virescens in association with summer broods of

*Other predators, in order of frequency: Plegaderus nitidus, Medetera aldrichii, Aulonium longum, Thanasimus lecontei (summer only), Platysoma punctigerum, Nudobius sp., Phloeonomus sp., Lonchaea sp., Tenebroides sp., Lasconotus sp., Derataphrus sp.

** Associates: Buprestid[illegible] ce[illegible]cids, Cossonos sp. Corticius sp. Pissodes sp.

D. monticolae appears to have a rather profound effect on the D.m. broods. This is most noticeable on the summer windfalls, particularly on trees which were lacking in this predator or contained only a trace, in comparison with those which contained one or more per unit of bark area.

3. The influence of other predators and associates on D.m. brood is apparently of little significance, since there is no correlation between their number and D. monticolae broods, even when large numbers are present.

4. The reduction of D. monticolae summer broods is quite definitely associated with the presence of T. virescens and this predator is therefore considered of profound importance as a biological control agency. By comparison, the controlling action of E. sphegeus on overwintering broods is of no consequence. However, the possibility of a combination of other factors coming in on summer broods to help influence the controlling action, which are absent on overwintering broods cannot be ignored and will require further study.

Comparative trends - 1937 and 1938.

By comparing the average numbers of T. virescens and E. sphegeus larvae per unit of bark area associated with the seasonal D. monticolae broods during 1937 and 1938, there has been in each case an apparent increase in numbers. The effect of the increase of E. sphegeus on overwintering D. m. broods during 1937-1938 was very slight, while the increase of T. virescens on summer broods was quite apparent. These data, however, while insufficient to make the case positive, indicate a trend, and also a need for annual checks of this nature, using a standard system of analysis. The figures for both years are presented for comparison.

TABLE II. Effect of Seasonal Increases of T. virescens and E. sphegeus on D. monticolae populations.

Season	Av. no. perdators per square foot		Av. no. D.m. per sq. ft.	Basis - no. samples
	T. vires.	E.spheg.		
1936-1937 overwinter	0	1.06	98.85	15 trees
1937 summer	.86	.1	75.08	15 trees
1937-1938 overwinter	0	2.97	83.75	5 trees
1938 summer	1.90	0	39.60	5 trees

BIOLOGICAL CONTROL EXPERIMENTS

The controlling influence of T. virescens and E. sphegeus was tested in experiments set up using caged green logs and caged portions of living trees in much the same manner as the preliminary test carried on in 1937. In addition, tests were set up to compare the controlling action of the clerid Thanasimus lécontei and the Dolichopodid (Diptera) Medetera aldrichii. In all tests set up, great care was taken in providing uniform rearing conditions and to prevent contamination with other insects by careful caging to exclude all except the insects to be studied. In each experiment, the green logs were first infested by D. monticolae adults which had previously emerged from a rearing cage containing D. monticolae brood. The predators to be studied were as a rule liberated in a given cage no less than 24 hours after the D. monticolae adults, to prevent them from being devoured before they had a chance to get established.

The amount of control by a given predator was determined by comparing the D. monticolae broods with check logs or trees from which predators were excluded. The most desirable, and in fact, the most reliable information was obtained by allowing the D. monticolae broods to develop to the adult stage and emerge. The final results could then be determined by comparing the numbers of beetles emerging from the checks and predator controlled logs. Actually this was possible in only one instance because of the onset of cold weather, making it necessary to close down the experiments. In all except the one test the bark was removed from the checks and predator controls where counts were made on D. m. brood and the number of predator larvae after the D. m. brood had developed to the mature stages. The results of these experiments are presented briefly.

Experiment 1. Effect of T.v.c. determined by emergence of D.m.

This experiment was carried on in two compartments of the screen insectary (Photo #2), each compartment containing 10 green logs with an approximate bark area of 100 square feet. A total of 1,622 D.m. adults was admitted to each cage on July 6. Between July 9 and 12, 100 T.v.c. adults were admitted to the predator control cage. The new D.m. generation began to emerge August 30 and continued until October 25. A total of 206 adults emerged from the control logs and 2,187 adults from the check logs. The control for the experiment amounted to 91 percent.

Experiment 2. Effect of T.v.c. compared with other predators determined through brood counts on logs.

Five logs were caged each separately in muslin type insect tight cages. (Photo #3). D. monticolae adults were admitted to each log at the rate of 18 to 29 per square foot. Predators were introduced into the biological control cages at the rate of 3 per square foot, except M. aldrichii which were introduced at the rate of 10 per square foot. At the end of 6 weeks the bark was removed from each log and counts were made on the numbers of D.m. brood and predator larvae. The

results presented in Table 3, which follows, show the comparative biological control for each predator in relation to the check.

TABLE III. Effectiveness of Predators Compared with Checks.

Predator	Log #	Bark Area	Pred. per Sq.Ft. Adults introduced	Pred. per Sq.Ft. Larvae	D.m. total	D.monticolae per sq.ft. No. attacking	D.monticolae per sq.ft. Attacks	D.monticolae per sq.ft. Brood	Control %
Check	M-7	6.9			711	18	4.2	103.0	
T.vires.	M-8	7.0	3	5.4	147	18	4.0	21.0	80
E.spheg.	M-9	6.5	3	.3	662	18	5.0	101.8	0
T.lecon.	M-5	5.8	3	.5	890	21.5	5.7	153.4	0
M.ald.	M-3	5.1	9.8	0.0	216	29.4	9.0	~~187.3~~ 42.3	0

These results show definitely that T. virescens was the only predator having any effect on the D. monticolae brood. The reasons apparently are explained by the failure of the others to get established under the caged condition. T. virescens was shown to be much more adaptable to the experiment. Consequently these data cannot be relied on as criteria for judging relative effectiveness under field conditions.

Experiment 3. Effect of predators on broods established on living trees. (Photo #4)

The basal portions of three small sugar pines ranging in diameter between 10 and 12 inches were enclosed in cylindrical screen cages from 2 to 11 feet above the ground on July 12-15, 1938. These were infested with D. monticolae adults at the rate of 25 to 30 to the square foot of caged bark area. One of the trees was used as a check, one was used to test the effect of T. virescens, and one the effect of M. aldrichii. These trees were cut on September 15 and the infested length transported to rearing cages where emerged adults could be counted. Since only a portion of the brood had emerged by October 25 when it became necessary to close down the experiment, the bark was removed and counts were made on the remaining brood. The results of this experiment are summarized in table 4, which follows.

TABLE IV. Effect of predators on D.m. broods through cage control on living trees.

Predator	Tree #	Bark Area sq.ft	Pred. per sq.ft Adults introduced	Pred. per sq.ft Larvae	D.m. total	D.monticolae per sq.ft. No. attacking	D.monticolae per sq.ft. Attacks	D.monticolae per sq.ft. Brood	Control %
Check	3	19.9			2295	25.4	8.6	115.6	
T.vires.	1	17.1	2.3	3.4	892	29.2	5.2	52.2	55
M.ald	2	17.7	5.6	.05	2066	28.2	6.1	116.6	0

Medetera aldrichii again showed no tendency to propogate under the caged condition, hence there was no control.

A definite controlling tendency was exhibited by T. virescens, but the amount was considerably less than that exhibited by the results from the logs. This is explained to a large extent by the smaller number of predator larvae per unit area compared with the number in the logs.

Conclusions.

The results obtained in all the biological control experiments carried on thus far have given rise to the following conclusions:

1. That T. virescens is consistent in its tendency to propogate and exert a definite controlling action.

2. That T. virescens is adaptable to the controlled conditions required for experimental work and performs normally.

3. That none of the other predators studied (E. sphegeus, T. lecontei, M. aldrichii) are readily adaptable to caged conditions and do not react to provide any reliable information.

4. That the total amount of biological control exerted by a given predator cannot be determined except through making a comparative count between predator controls and checks on the number of beetles which developed to maturity and emerged.

5. That there is apparently a minimum number of T. virescens in the larval stage required before effective biological control can be expected. Data obtained indicate 5 larvae per square foot are sufficient for effective control.

FACTORS AFFECTING EFFICIENCY

Specificity of host.

There is no specificity in regard to the various species of Scolytidae, but specificity is apparent when considering Scolytidae as a group, compared with other families of Coleoptera.

1. Association with other scolytids.

Preliminary determinations of this factor with T. virescens [illegible] E. sphegeus were obtained by quantitative data taken from 5 ponderosa pines infested by D. brevicomis and Ips confusus, 2 sugar pines infested by Ips confusus, and one white fir infested by Scolytus ventralis. In addition, 200 square feet of bark area from windfall ponderosa pines infested by Ips confusus was analyzed. A tabular summary of these data is presented.

TABLE V. *T. virescens* and *E. sphegeus* association with other scolytids.

Season	No. trees	Bark area sq. ft.	No. predator larvae per sq.ft. *T. virescens*	*E. sphegeus*
	Host: *D. brevicomis* in ponderosa pine.			
1937 summer	2	8	2.1	0
1937-1938 overwinter	2	16	0	.2
1938 summer	1	15	3.2	0
	Host: *Ips confusus* in ponderosa pine			
1937 summer	1	4	.7	0
1937-1938 overwinter	2	10	0	0
1938 summer	windfalls	200	.5	.6
	Host: *Ips confusus* in sugar pine			
1938 summer	2	4	1.7	.7
	Host: *S. ventralis* in white fir			
1937-1938 overwinter	1	10	1.2	0

These data indicate that neither of these predators is entirely specific in relation to *D. monticolae*, and that they are definitely associated with other species of scolytids. This is especially shown to be true of *T. virescens* which was well represented in association with the summer broods of all of the species examined.

2. Association with flatheads.

Judging from observations made in connection with pure flathead (*M. gentilis*) infestations, neither one of these predators has been found to be important. As a rule they are entirely absent unless this flathead infestation is mixed with *D. monticolae* or other scolytids, in which case the predators are attracted apparently by the scolytids.

Quantitative information on this point was taken from only one pure flathead sugar pine, in which the brood had developed to the fully grown larval stage. In 15 square feet of bark carefully analyzed, not one predator was found.

Other Factors Compared.

In the following tabular summary, a comparison is made between *T. virescens* and *E. sphegeus* in relation to a number of factors which limit their controlling action or effeciency. Most of the data used as a basis for this comparison were obtained from controlled laboratory experiments, at continuous temperature near 75° F. Hence the results obtained are possibly somewhat more rapid than would be the case under field conditions.

TABLE VI. Comparison of Predator Efficiency Factors.

Factor	T. virescens	Basis	E. sphegeus	Basis
Longevity, adults				
Average	5. months	74 ad.	2 months	36 ad.
Maximum	8 months		3 months	
Fecundity				
Av.eggs per female	300	37 ♀♀	40-60	18 ♀♀
Max.eggs/one "	581	1 ♀	92	1 ♀
Fertility				
Average percent	71	125 eggs	60	28 eggs
Control				
Adults	2 per day	11 ad.	.9 per day	10 ad.
Larvae	40-70 per life	1200 larv.	15-30 per life	500 larv.
Life cycle				
Minimum	70 days	100 spec.	60 days	500 spec
Average	240 days	100 spec.	80 days	500 spec.
Maximum	Undetermined		Undetermined	
Hardiness	++++		+-	
Adaptability	++++		-	
Cannabalism	+		+	

In all factors except length of larval life, T. virescens appears to have a distinct advantage as a biological control agency over E. sphegeus. The average length of larval life for T. virescens is much greater than that of the host. Consequently there is apt to be considerable mortality of brood from starvation unless they feed on associated insects of different species under the bark, which is probably the case, or on new generations of the host developed lower down on a tree. The average larval life of E. sphegeus is only slightly longer than that of the host and there is much less possibility of starvation.

Since both species have a one-year life cycle, neither one has a controlling advantage over the other from the standpoint of time. E. sphegeus loses considerable time in a long aestivation period of mature larvae before pupation. From the standpoint of predatory ability of larvae, T. virescens is almost 3 times as efficient as E. sphegeus. Therefore, it appears that even though T. virescens has a much longer larval life than E. sphegeus, it is active during this period and destroys many more host larvae. Where more than one generation of D. monticolae are developed in the same tree, which is commonly the case, it is possible for one T. virescens brood to work on both D.m. broods and thus increase their predatory efficiency.

CONCLUSIONS AND SUGGESTIONS FOR FURTHER STUDY.

These infestigations have shown quite definitely that the green trogositid, Temnochila virescens is the most promising of all species of

native predators in the control of the mountain pine beetle. While the red bellied clerid is a much better actor and in general is a vicious-looking, fast-moving predator, experimental evidence so far has shown it to be far less effective. It is important, therefore, that continued studies should be developed and centered around T. virescens in anticipation of its use in the development of biological control.

In the continuation of studies on predator control it is essential that more field information be secured in relation to the seasonal development of D. monticolae to determine: (1) the initial establishment of eggs and larvae; (2) the population maintenance or decrease with the advancement of D. monticolae broods; (3) the habits of larvae following the completion of the D.m. life cycle in trees of different infestation types; (4) the relation to the control of D. monticolae; (5) the relationship with other primary tree-killing insects.

These studies should be supplemented by more controlled rearing experiments to further test their predatory efficiency in regard to: (1) the number of adults per unit of bark area needed for establishment of sufficient larvae for effective control; (2) the number of larvae needed per unit of bark area for effective control; (3) the minimum number of host larvae needed to support a given number of predator larvae per unit of bark area.

In the practice of artificial control against the mountain pine beetle the protection of predators is of high importance. The development of protective methods for predators in relation to whatever method is used has been considered for some time. Studies along this line should be initiated as soon as possible.

SUMMARY

Studies were continued during 1938 on the seasonal history, abundance, and controlling action of the green trogositid and red bellied clerid in relation to the mountain pine beetle in sugar pine. Field data and brood material for laboratory study were taken from the same general areas as last year, near Wawona, California. Improved laboratory and rearing facilities at the newly established Miami Laboratory aided materially in the accomplishment of this program. The results have provided a much stronger basis to continue investigations on biological control. The most important facts determined are presented briefly.

1. In general, little departure in total life period for each predator was noted in comparison with 1937; both species have a one-year life cycle in their native habitat. The green trogositid larval period, however, was found to be much longer than at first anticipated, with an average period of 240 days at a constant temperature of 75° F.

2. Further data on the association of these predators with D.m. has established the fact that E. sphegeus is definitely associated with the overwintering larval brood and T. virescens with the summer broods.

3. The controlling action under natural field conditions of T. virescens is much greater than E. sphegeus, as evidenced by field data The presence of T. virescens in numbers over 1.5 per square foot has an appreciable effect, while little effect was evident where as many as 5 E. sphegeus larvae per square foot were found.

4. Under cage-controlled conditions T. virescens in tests in green logs, destroyed between 80 and 91 percent of the D.m. brood by comparison with checks.

5. Under the same conditions for E. sphegeus the control amounted to from 0 to 20 percent in all tests. Failure of E. sphegeus to become established under caged conditions partly explains the result.

6. Comparative tests of this nature tried on the Dolichopodid (Diptera) Medetera aldrichii and the clerid Thanasimus lecontei resulted in no control, but this is explained by failure of establishment under caged conditions.

7. A test of the controlling action of T. virescens on a caged living tree attacked by D.m. resulted in 55 percent control. Larvae numbering 3.4 per square foot of bark area were found. By comparison with the 80 percent control in logs, where 5.4 larvae per square foot were found, it appears that the number established per unit area is an important factor limiting control.

8. These predators are commonly associated with other species of primary scolytids - D. brevicomis, Ips confusus, and Scolytus ventralis, but are not found with flatheads unless the infestation is mixed with scolytids.

9. Laboratory tests comparing a number of efficiency factors in consideration of biological control have definitely established that T. virescens is the most promising of native predators for use in developing biological control of the mountain pine beetle.

Photo 1. (99738) Making population counts on D. monticolae and predators along main bole of infested sugar pine. Information of this character is helpful toward a better understanding of the relationship between predators and D. monticolae brood control. Photo by J.E.Patterson.

Photo 2. (9972H) Compartment rearing unit composed of eight parts, each securely screened so that several different experiments can be carried on at once. This is particularly valuable in testing the effect of predator control on the mountain pine beetle. Photo by J.E.Patterson.

Photo 3. (9973E) Individual rearing cages used in testing the predatory efficiency of T. virescens, E. sphegeus, Medetera aldrichii, and Thanasimus lecontei. Green sugar pine logs, each having a bark area of ± 5 square feet were first infested by the mountain pine beetle, following which a given number of predator adults were introduced to lay eggs and establish broods. The total effect of predators was determined by comparison of emergence of new adult D. monticolae with check logs from which predators were excluded. Photo by J. E. Patterson.

Photo 4. (9973L) Predator efficiency on living trees attacked by the mountain pine beetle. The basal 10 feet of small sugar pines of uniform type were infested by enclosing this area in insect tight, screen cylinders and then liberating D. monticolae adults to attack at a rate of 15 to the square foot of enclosed bark area. Predators of a given species were liberated 24 hours after each D. monticolae introduction. Results were determined by making comparative counts of new adults emerging from checks and predator controls. Photo by J. E. Patterson.